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TEST OF RAILWAY GENERATOR, ENGINE, AND CONDENSING PLANT.

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Test of Railway Generator, Engine and Condensing Plant

The test here described was made in May and June 1901 at one of the large power stations in Philadelphia. By request of the company owning the plant the names of builders and owners are withheld.

The outfit tested consists of a 2000 H.P. cross compound Corliss engine direct connected to a 1500 K.W. railway generator, a surface condenser with motor driven air and circulating pumps and a cooling tower.

The object of the test was to determine, as far as possible, the efficiencies and losses in the various parts of the plant and to find what gain is made in running condensing rather than noncondensing.

Following is a brief description of the various parts of the plant. The cylinders of the engine are 30" and 60" in diameter respectively, with a stroke of 60". The engine works at about 140 lbs. initial pressure and 80 revolutions per minute and can be arranged to run either condensing or noncondensing. In the latter case it exhausts through feed heaters to a stack in common with the other engines

in the station.

The generator is a direct current machine with a rated capacity of 2730 amperes at 550 volts. It is generally run at from 560 to 570 volts.

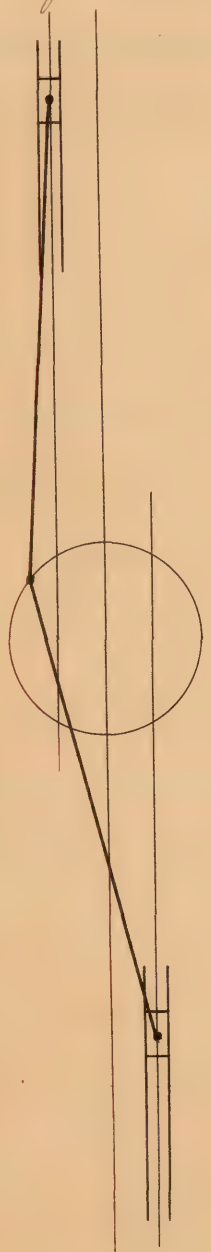
At present the condenser is arranged to empty the condensed steam into the sewer but piping is being put in to carry this water to the hot well to be returned to the boilers. The air pump is a two cylinder short stroke bucket pump geared to a 20 H.P. electric motor. Cooling water is supplied to the condenser by a centrifugal pump directly driven by a 75 H.P. electric motor. The

pump draws water through a line of 15" pipe from the cooling tower at the rear of the power house. The tower rests on a small building and is made up of wrought iron plates. It is 22'10" x 14'3" and [illegible] in height. Water coming from the condenser enters at the top of the tower and after trickling down over galvanized iron mats, collects at the bottom and is returned to the condenser. A large volume of air is passed upward over the mats by four fans placed two on each side of and at the bottom of the tower. The fans are driven from two shafts by an 8½" x 8" Westinghouse Standard engine. A considerable

quantity of water is lost by evaporation in the tower and this is made up from the city main the amount being registered by a water meter. This supply is regulated by a float valve in the tank at the bottom of the tower.

As a part of the test it was necessary to find the power used up in the various auxiliary apparatus. On May 13 indicator cards were taken from the engine running the fans, certain parts of the system not being in condition to test at that time. For this purpose a special indicating rig was made consisting of two small wooden crossheads

and connecting rods run from a crank pin in the end of the shaft The crossheads moved in guides attached to a vertical frame at the side of the engine and were set off center by one half the distance from the center of the shaft to the center of the pin. The arrangement is shown in the diagram The connecting rods were made two and a half times the length of the stroke, as in the engine itself, so that the exact motion of the



latter was reproduced by the rig.
Indicators were attatched to the
top of each cylinder at the opening
leading to the relief cock. Strings
were led from them through
glass tubes and attatched by
hooks to short lengths of string
fastened to the crossheads. The
engine ran at over 350 revolutions
per minute and after several
trials string was discarded
owing to the excessive stretch.
Fine piano wire was substituted
and excellent results were
then obtained. The test lasted
50 minutes. Cards were taken
every 5 minutes and revolutions
were recorded by a continuous
counter. Water was kept passing
through the tower during

the test For data and results of this test see page 23.

A non-condensing preliminary test was made on May 6, to determine the commercial efficiency and frictional and electrical losses of the engine and generator Cards were first taken with the engine running at full speed with no load and generator fields unexcited, and then with no load but with shunt field excited and dynamo up to full voltage. Following this, load was thrown on in steps of about 500 amperes. Simultaneous readings were taken on the machine ammeter and voltmeter from which the

output of the unit was determined.
Three sets of cards were taken
for each load. In order to get
cards at the same instant which
the electrical readings were
taken six men were employed,
one at each of the four indicators
one at the voltmeter and one
at the ammeter. The observer
at the ammeter was provided
with a whistle and when the
load was what was desired
cards and readings were
taken as he blew it. This method
was necessitated by the very
fluctuating load. Revolutions
were recorded by a continuous
counter run from the exhaust
valve gear and were noted,
with the corresponding time,

just after each card was taken. Initial and receiver pressures were read at regular intervals as was the shunt field current

As mentioned above four indicators were used placed as near as possible to the ends of the cylinder. The motion for the drums was obtained from a permanent rig on the engine. On the cross-head is fastened a sleeve which slides along a shaft parallel to the guides and supported on bearings at each end. The shaft has a helical groove cut in it into which fits a pin in the sleeve, held down by a strong spring so that as the cross-head moves the shaft revolves. By means of string fastened to a

wheel on the end of this shaft the motion is carried to the indicators To prevent lost motion the groove is made with slanting sides and the pin is tapered to fit. The gear is controlled by a handle on the cross head, which either lets the pin down into the slot or pulls it out entirely and leaves the shaft free.

Data and results of this test are seen on pages 24 to 30. The efficiency is calculated for each set of cards and as seen from the curve on page 28 the values so obtained are close together for approximately equal loads.

The principal test was made on June 8 with the entire condensing system in operation. It was made

in two parts the first lasting 134 minutes and the second 68 Minutes and beginning ten minutes after the first part had ended. In the first part the pump was run with as good a vacuum as could be obtained while in the second a joint in the exhaust pipe between the low pressure cylinder and the condenser was broken and the vacuum was allowed to fall as low as it would, the air pump being used only to clear the condenser of the condensed steam. The condenser pressure was then almost atmospheric there still being about 2" vacuum.

Before the test all watches were compared and set by

me as a standard. Each man employed on the test had a distinct set of readings to make, which were made independently of the others.

The general readings, (see pages 31 to 37) which required two men, were taken in regular order at intervals of ten minutes. Indicator cards were taken simultaneously by two men, one at each cylinder. They were taken at intervals of five minutes at the sound of a whistle blown by the man at the high pressure cylinder. The electrical readings on the generator, including voltmeter ammeter and wattmeter, were taken by one man. Voltmeter and ammeter readings were

taken simultaneously at half minute intervals and the wattmeter was read every five minutes. The true multiplier for the latter was obtained from the voltmeter and ammeter readings.

The condensed steam was run into tanks and weighed. Three tanks were used for this purpose each placed on a platform scale and emptying into a pipe leading to the city sewer. The circulating water owing to the fact that a suitable meter was not obtainable was measured by Pitot tubes placed in the pipe lines leading from the cooling tower to the condenser. Care was taken to place them at a point in a

considerable straight length of pipe.
The constant used in the calculation
is obtained from an investigation
of Pitot tubes by H. N. Rodenbaugh.
Two traps are used in connection
with the engine, one to drain the
high-pressure jacket and the
other to drain the receiver and
low-pressure jacket. The water
collected in these was determined
and added to that used in
the cylinders of the engine to
obtain the water rate. Pipes
leading from the traps were run
to a barrel placed on a platform
scale. The method used to
determine the rate at which
this water was discharged was
as follows. The barrel was partly
filled with cold water and

the discharge from the traps collected for a certain time. The original and final weights were noted and a rate obtained from the mean of a number of such observations made at intervals during the test.

The Westinghouse engine running the fans on the cooling tower had been previously tested on May 13 as described above. During the condensing test on June 8 the engine ran at a slightly higher speed and correction for this is made by assuming the horse power proportional to the revolutions per minute.

All instruments and apparatus used during the tests

were, as far as possible, calibrated and tested for accuracy before working up the results.

The calibration of indicator springs was performed as follows. Each spring was placed in the indicator in which it was used during the tests and the indicator and a steam gauge connected to a point where full steam pressure could be obtained. The pressure was regulated by a valve so as to rise or fall slowly and for each 10 lbs. rise or fall by the gauge a line was drawn on the paper attached to the indicator drum. The gauge was afterwards calibrated and from the rise or fall of the indicator pencil corresponding to various

pressure differences the true scale of the spring was obtained. In calibrating springs for pressures below atmospheric the same method was employed the indicator being attached to a condenser exhausted by an air pump, and pressures being read by a mercury U tube of which one leg was open to the air and the other attached to the condenser.

The wattmeters in the circuits of the generator and air and circulating pumps were calibrated by the voltmeter and ammeter readings taken during the test. The generator voltmeter was calibrated by comparison with a standard placed in various positions with reference

to the switch board, so as to correct as far as possible, for the error due to the magnetic field in the vacinity.

The scales used in weighing condensed steam and the discharge from the traps were tested by adding a known weight and reading the original and final weights. One of the former scales was found slightly inaccurate and was further calibrated by the addition of a known volume of water. See page 39.

All thermometers used were afterward placed in water at various temperatures and referred for calibration to a standard thermometer placed

in the same vessel.

In order to calibrate the water meter on the make up for the cooling tower the tank at the bottom of the tower was nearly emptied and then allowed to fill up the quantity of water being registered by the meter. The tank was carefully measured also the depth of water before and after the test and from these readings the calibration was worked up. See page 44.

OBSERVATIONS AND RESULTS.

TEST OF WESTINGHOUSE ENGINE RUNNING FANS ON COOLING TOWER.

5/13/01.

	Time	Counter Readings
	3.30	72336
	4.20	90488
Difference	0.50	18152

Duration of Test - 50 min.

{ Cylinder - 8½"
{ Stroke - 8"

Mean R.P.M. = 363.04

Indicator Cards.

Cylinder	Number of Indicator	Cards Taken	Mean Area.	Mean Length	Mean Ordinate	Spring Scale	M.E.P.
Near	3071	6	2.138	3.788	.564	95.83	54.0
Off.	2409	5	2.140	3.796	.562	80.46	45.3

$$I.H.P. = \frac{(P_1 + P_2)LAN}{33000} = \frac{(54.0 + 45.3) \times 8 \times 56.745 \times 363.04}{12 \times 33000}$$

$$= 41.22.$$

Preliminary Test of Engine and Generator. 5/6/01.

1. External Circuit and Shunt Field of Generator open.

4 sets of Cards taken

Mean R.P.M. - 81.43

	I.H.P.
High Pressure Cylinder	71.68
Low Pressure Cylinder	5.07
Total.	76.75

Engine Constants.

Diam. H.P. Cylinder - 30"

" L.P. " - 60"

" Piston Rods - 7"

Stroke - - 60"

$$\text{Constant} = \frac{\frac{A_H + A_c}{2} \times L}{33000} =$$

H.P. Cyl.	L.P. Cyl.
.10418	.42548.

2. Shunt Field Excited; External Circuit open.

4 sets of cards taken.

Mean R.P.M. - 81.43.

	I.H.P.
H.P. Cylinder -	185.07
L.P. " -	33.15
Total I.H.P. -	218.22

3. Generator running at various Loads.

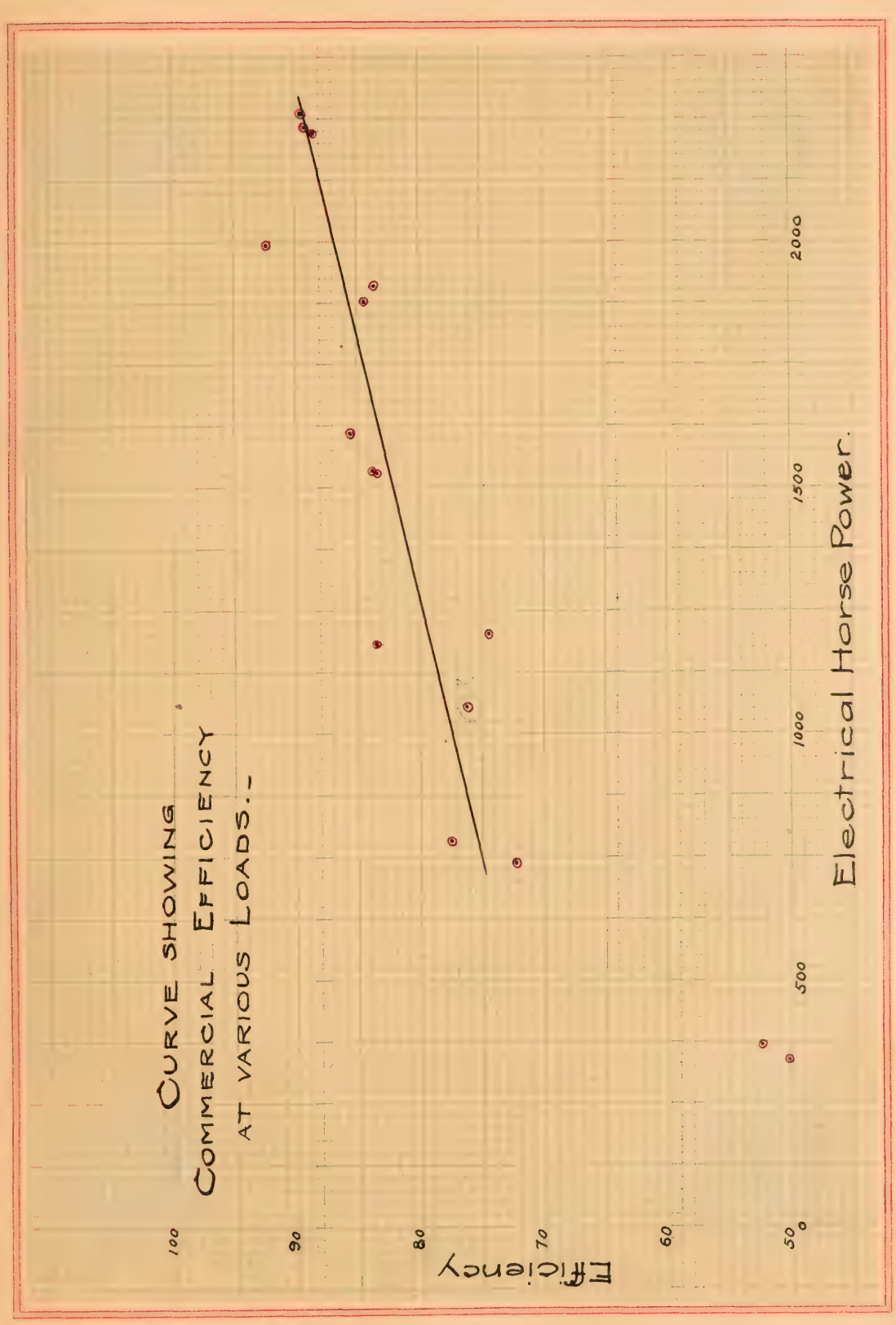
Observations and Results on pp. 26 to 28

3. Observations. 5/6/01.

No.	Time	Steam Pressure	Receiver Pressure	Amperes Shunt Field.	Amperes Ext. Circuit.	Voltage at Terminals.
1	3.31.			14.2	500	552
2	3.33.30	138	26.0	14.1	500	555
3	3.36.	138	25.5	14.1	460	550
4	3.38.	138	24.7	14.0	1050	550
5	3.40.30	139	25.0	14.1	1000	554
6	3.42.30	140	24.5	14.0	1050	562
7	3.48.	145	29.2	14.3	1550	565
8	3.54.	148	31.0	14.0	1600	562
9	3.56.	147	30.8	14.4	1550	573
10	4.03.	144	27.5	15.0	2000	573
11	4.05.	144	28.0	14.8	2000	570
12	4.07.	141	26.5	14.1	2100	572
13	4.11	141	25.2	14.0	2600	572
14		145	26.1	13.8	2550	560
15	4.16.30	149	26.0	14.2	2500	560
16	4.25.15	132	24.0	14.1	2980	557
17	4.28	131	23.8	14.0	3000	555
18	4.30.30	134	24.2	14.1	3030	557
Means	0.59.30	140.8	26.4	14.18		561.4

3. RESULTS. 5/6/01

Card No.	Mean R.P.M.	I.H.P. H.P. Cyl.	I.H.P. L.P. Cyl.	I.H.P. Total.	Electrical Horse Power	Commercial Effiency (%)
1						
2	80.80	486.6	221.6	708.2	371.95	52.53
3		478.7	199.0	677.7	339.16	50.05
4		664.2			774.16	
5	80.50	692.4	335.8	1028.2	742.60	72.24
6		684.1	334.1	1018.2	790.96	77.69
7		880.1	640.4	1520.5	1158.50	76.19
8	79.85	893.4	729.1	1622.5	1205.28	74.29
9		823.4	601.3	1424.7	1190.55	83.51
10		1033.0	796.1	1829.1	1536.20	83.98
11	79.41	975.4	851.5	1826.9	1528.20	83.63
12		1078.0	801.1	1879.1	1610.07	85.69
13		998.1	1163.0	2161.1	1993.34	92.23
14	78.82	1273.0	1012.0	2285.0	1914.28	83.76
15		1246.0	974.9	2220.9	1876.75	84.42
16		1433.0	1083.0	2516.0	2224.86	88.44
17	78.07	1453.0	1053.0	2506.0	2231.70	89.07
18		1455.0	1075.0	2530.0	2262.19	89.41


Curve showing
Commercial Efficiency
at various Loads.-
Efficiency
100
90
80
70
60
50
0
500
1000
1500
2000
Electrical Horse Power.

Generator Losses and Friction.

I. H. P. required to drive Generator with no current, as in Part 1, of the test = 76.75 H.P.

To drive Generator with shunt field fully excited, as in Part 2, required 218.22 H.P.

In Part 3, for cards no. 18, I.H.P. = 2530.0 and E.H.P. = 2269.19. H.P. lost was therefore 267.81 which included friction, shunt and series field C^2R losses and hysteresis and eddy current losses at full load. Assuming the friction H.P. = 76.75 as above and with a shunt field loss of 10.53 H.P. $\left(= \frac{14.1 \times 557}{746}\right)$, a total of 87.28 H.P., — 180.53 H.P. remains as series field and magnetic losses.

The difference between the H.P. of Parts 2 and 1, or 141.47 H.P. is made up of shunt field loss and magnetic losses at no load. Taking the former = 10.53 H.P as before, we have the remainder or 130.94 H.P., as magnetic losses at no load.

The difference between 180.53 and 130.94, or

49.55 H. P. is evidently the difference between the magnetic losses at full load and no load plus the series field loss at full load.

The losses for #18 of Part 3 may be set down as follows, approximately :-

Loss	H. P.	%
Friction	76.75	28.7
Shunt Field	10.53	3.9
Series Field, Hysteresis and Eddy Currents	180.53	67.4
Total	267.81	100.0

The total loss in the generator is 191.06 H.P. and its electrical effiency is $\frac{2269.19}{2460.25} = 92.2\ \%$

Condensing Test and Non-Condensing Test. 6/8/01.

Condensing Test - 134 min.. 1.15 P.M to 3.29 P.M.

Non-Condensing Test - 68 min.. 3.36 P.M. to 4.44 P.M.

(Set 1.) General Observations (Condensing)

Time	Water Meter (cu. ft.)	Temp.[x] entering tower	Temp. leaving tower	Temp. make-up	Temp. entering condenser	Temp. leaving condenser	
1.15	2538	112	89	75	89	108	
1.27	2621	113	89	75	88	113	
1.40	2707	117	93	75	93	122	
1.49	2782	120	91	76	92	114	
1.59	2860	118	92	75	93	122	
2.09	2937	127	96	75	96	124	
2.19	3025	111	91	75	89	107	
2.29	3095	103	85	75	85	103	
2.39	3146	106	86	74	85	106	
2.49	3194	107	85	74	84	104	
2.59	3255	112	86	74	85	110	
3.09	3312	109	86	73	85	108	
3.19	3374	110	86	73	86	108	
3.29	3434	106	86	73	86	107	
2.14	896	112.2	88.6	74.4	88.3	111.1	Mean
		111.9	88.3	74.4	88.0	111.4	Mean Corrected

Totals ——

[x] All temperatures expressed in degrees Fahr.

6/8/01

(Set 1) General Observations (Condensing) Cont'd.

Temp. Condensed Steam	Vacuum at Condenser	Circulating Pump Pres. Entrance	Circulating Pump Pres. Exit	R.P.M. Circulating Pump	R.P.M. Air Pump	R.P.M. Fan Engine.
104	26.0"	3.75	23.0	368	132	
94	26.0	3.60	23.0	370	134	
100	26.5	3.50	23.0	368	130	
96	26.9	3.50	23.2	356	132	
98	26.2	3.50	23.5	360	132	
113	25.0	3.50	23.0	368	130	
98	26.5	3.75	23.0	372	134	
90	26.7	3.75	22.8	356	132	
88	26.8	4.00	22.5	350	132	
86	26.7	3.80	22.5		134	370
85	26.8	3.80	22.8		132	371
86	26.8	3.80	22.5		132	370
86	27.0	3.75	22.8		130	373
90	27.0	—	—		—	372
93.9 93.5	26.9	3.69	22.89	363.1	132.0	371.2

Means.

6/8/01

(Set 1) General Observations (Non-condensing)

Time	Water Meter (cu. ft.)	Temp. entering Tower	Temp. leaving Tower	Temp. make-up	Temp entering Condenser	Temp. leaving Condenser
3.46	3523	123	90	73	89	115
3.59	3626	133	92	73	90	112
4.09	3724	125	90	73	89	110
4.19	3808	120	89	73	86	105
4.29	3886	115	89	73	88	104
4.39	3960	120	89	73	89	107
4.49	4030	122	90	73	88	106
1.03	507	122.6 122.3	89.9 90.0	73.0 73.0	88.4 88.1	108.4 108.7

6/8/01

(Set 1) General Observations. (Non-condensing). Cont'd.

Temp. Condensed Steam	Vacuum at Condenser	Circulating Pump Pres. Entrance	Circulating Pump Pres. Exit	Temp. Dry Bulb	Temp Wet Bulb	R.P.M. Fan Engine	
94	2.2"	4.00	22.0	73	59	369	
94	2.2	4.00	22.3	73	59	370	
95	2.0	4.00	22.5	73	59	372	
96	2.0	4.00	22.5	73	59	372	
94	2.0	4.00	22.5	73	59	370	
95	2.0	4.00	22.5	73	60	371	
96	2.0	4.00	22.5	73	59	373	
84.9 94.5	2.06"	4.00	22.40	73.0 72.7	59.1 58.8	371.0	Means.

Relative Humidity (Kent p-483) = 41.9.

6/8/01

(Set 2) General Observations (Condensing)

Time	Wattmeter reading (Air Pump)	Wattmeter (Circ. Pump)	Pitot Tubes. Left.	Right	Difference (inches)
1.15	3,994,010	19360	16.7"	4.8"	11.9"
1.25	,060	19770	14.2	6.7	7.5
1.35	,120	20185	16.7	5.2	11.5
1.45	,170	20603	16.5	5.1	11.4
1.55	,220	21038	16.7	5.0	11.7
2.05	,280	21485	16.6	6.0	10.6
2.15	,330	21928	16.7	6.5	10.2
2.25	——	22355	17.0	6.8	10.2
2.35	,430	22785	17.5	7.0	10.5
2.45	,480	23192	18.2	8.0	10.2
2.55	,530	23585	17.8	8.0	9.8
3.05	,570	23935	18.2	8.0	10.2
3.15	,620	24388	18.5	8.0	10.5
3.25	,670	24798	18.2	8.0	10.2
3.35	3,994,730	25215	—	—	—
2.20	720	5855			10.46"
	Totals ——				Mean.

6/8/01.

(Set 2) General Observations. (Condensing). Cont'd.

Counter reading (Main engine)	Receiver Pressure	Vacuum in Exhaust pipe	Calorimeter.— Steam Pressure	Upper Temp	Lower Temp.
	lb.	"	lb.	°F.	°F.
72426	19.6	23.0	152	361	293
73226	18.5	22.3	148	356	292
74024	18.5	17.5	144	356	292
74814	17.9	23.5	148	356	293
75612	19.5	20.8	151	358	294
76404	17.5	18.0	140	354	291
77189	19.0	21.4	151	358	294
77993	17.5	23.0	157	361	296
78798	16.5	22.8	157	361	295
79603	15.0	23.2	151	358	294
80405	17.4	23.1	154	359	294
81208	17.0	22.6	150	357	295
82009	16.2	23.0	148	356	295
82810	17.8	23.1	157	360	296
83612	—	—	—	—	—
11186	17.71	21.95	150.6	357.9	293.9

Mean R.P.M. 79.90

Corrected 144.14

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6/8/a.

(Set 2) General Observations. (Non-condensing)

Time	Counter (Main engine)	Receiver Pressure	Vacuum in Exhaust Pipe	Pitot Tubes. Left	Right	Difference	Calorimeter. Steam Pressure	Upper Temp.	Lower Temp.
		lb.	"	"	"	"	lb	°	°
3.45	84474	21.8	5.0	18.0	9.2	8.8	151	359	296
3.55	85268	20.0	5.0	18.1	9.4	8.7	136	353	292
4.05	85974	19.5	5.0	18.6	8.6	10.0	140	354	291
4.15	86846	19.8	5.0	18.3	9.4	8.9	142	354	292
4.25	87643	21.0	5.0	18.3	9.2	9.1	150	358	294
4.35	88439	21.2	5.0	18.8	9.2	9.6	152	359	296
4.45	89237	21.5	5.0	18.6	9.3	9.3	152	358	298
1.00	4763	20.69	5.00			9.20"	146.1	356.4	294.1

Mean R.P.M. . 79.38. Corrected 141.17

Calibration of Wattmeter on Air Pump Motor.

Ammeter and voltmeter readings were taken every 15 sec. from 1.36 to 1.46 P.M. The mean power during the time was 5889 watts. Wattmeter readings :- $\frac{1.46 \;.\; 3994175}{1.36 \;.\; 3994125}$ $\frac{}{50}$ watt hrs.

$50 \div \frac{1}{6} = 300$ watts. Multiplier $= \frac{5889}{300} = 19.63$

The motor takes about 11 amp. at 540 volts.

Calibration of Wattmeter on Circ. Pump Motor.

Ammeter and voltmeter readings taken every 15 sec. from

Mean power 47642 watts

2.03.45 to 2.10.30 P.M. Motor takes about 100 amp. at 475 volts. Wattmeter readings :- $\left.\begin{matrix} 2.03 \;.\; 21350 \\ 2.10 \;.\; 21665 \end{matrix}\right\}$ $\frac{315}{}$ $315 \div \frac{7}{60} = 2700$ Multiplier $= \frac{47642}{2700} = 17.65$

6/8/01.

Steam Consumption (Condensing)

Tank 1.		Tank 2.		Tank 3.	
Time full.	Wt. of Water	Time full	Wt. of Water	Time full	Wt. of Water.
				1.17	728
1.20	2545	1.23	1463	1.24	828
1.30	2259	1.32	1523	1.35	904
1.38	1935	1.40	1507	1.42	840
1.44	1504	1.47	1555	1.48	791
1.51	1444	1.54	1488	1.55	748
1.57	2204	2.01	1556	2.03	899
2.05	2040	2.08	1449	2.09	851
2.11	1745	2.13	1349	2.15	853
2.17	1501	2.20	1528	2.22	794
2.26	2173	2.29	1508	2.34	845
2.37	2314	2.40	1537	2.45	838
2.47	1773	2.52	1496		
2.56	2385			2.58	861
		3.01	1504		
3.06	2331	3.10	1539	3.13	843
3.16	2291	3.20	1554	3.23	782
3.27	2367	3.29	1305		
	32811		23861		12405

Totals

6/8/01.

Steam Consumption. (Non-condensing)

Tank 1		Tank 2.		Tank 3.	
Time full.	Wt. of Water	Time full	Wt. of Water	Time full	Wt. of Water.
		3.38	1458	3.40	861
3.43	2352	3.47	1545	3.49	903
3.51	2119	3.54	1538	3.56	885
3.58	1658	4.00	1253	4.02	837
4.03	1829	4.06	1511	4.08	894
4.10	1861	4.13	1492	4.15	863
4.18	2178	4.21	1512	4.23	779
4.26	2423	4.29	1504	4.32	851
4.35	2431	4.39	1494	4.41	911
4.44	2247				
	19098		13307		7784

Calibration of Tank #3.

Area cross-section of tank = 5.98 sq. ft.

Depth of Water for calibration = $2'6\frac{1}{4}'' = 2\frac{25}{48}''$

Wt. full – 1265 lb.

" empty – 393

" water 872 "

$5.98 \times 2\frac{25}{48} \times 62.1 = 936.1$ lb. True Wt.

872.0

64.1 lb. error

$\frac{64.1}{936.1} = 6.837\ \%$ error.

6/8/01

Condensed Steam from Jackets and Receiver

Both Traps. (Condensing)

Time empty	Time full	Wt. empty	Wt. full	Net wt.	Rate (lbs. per min.)	
12.48½	12.53½	368	465	97	19.40	
1.12¼	1.16¼	415	480	65	16.25	
1.49	1.54¾	385	475	90	15.64	
2.29	2.42	298	480	182	14.00	
2.51	301	340	471	131	13.10	
					15.67	Mean

Mean rate per hr.- 940 lb.

L.P. Cylinder and Receiver Trap. (Condensing)

Time empty	Time full	Wt. empty	Wt. full	Net wt.	Rate (lbs. per min.)	
1.19	1.28	3.95	477	82	9.11	
2.00	2.18	298	450	152	8.44	
					8.77	Mean

Mean rate per hr.- 526 lb.
Mean rate per hr. for H.P. Cyl. Trap.- 414 lb.

Both Traps. (Non-condensing)

Time empty	Time full	Wt. empty	Wt. full	Net wt.	Rate (lbs. per min.)
4.34	4.44	2.80	408	128	12.8
				Mean rate per	hr.- 768 lb.

6/8/01

Indicator Cards.

Condensing. (28 sets).

Cards	Indicator	Mean Area	Mean Length	Mean Ordinate	Greatest Area	Least Area	M.E.P.	Horse Power
H.P. H'd.	3071	3.296	4.844	.68045	4.70	2.13	65.21	1049.6
H.P. Cr.	2409	3.422	4.861	.70407	5.15	2.12	60.87	
L.P. H'd.	1185	3.726	4.730	.78773	4.71	2.94	15.47	1057.0
L.P. Cr.	1406	2.397	4.979	.48142	3.14	1.95	15.61	
							Total	2106.6

Non-condensing. (15 sets).

Cards	Indicator	Mean Area	Mean Length	Mean Ordinate	Greatest Area	Least Area.	M.E.P.	Horse Power
H.P. H'd.	3071	3.803	4.847	.78473	4.42	3.06	75.22	1201.8
H.P. Cr.	2409	3.980	4.867	.81770	4.88	3.17	70.70	
L.P. H'd.	1185	2.531	4.720	.53616	3.11	2.20	10.53	781.6
L.P. Cr.	1406	1.893	4.866	.38895	2.24	1.50	12.61	
							Total	1983.4

Calibration of Indicator Springs.

Make of Indicator	No. of Indicator	No. of Spring	Spring scale (nominal)	Spring scale (actual)
Tabor	1406		30	32.41
"	1185		20	19.64
Thomson	3071		100	95.83
"	2409	3260	80	86.46
"	"	3257	80	80.46

Spring 3257 used on preliminary tests.
" 3260 " " " "

6/8/01

Electrical Horse Power.

{Ammeter and voltmeter readings every 30 seo.
Wattmeter " " 5 min.}

Mean watts found for every 10 minutes and a wattmeter multiplier calculated for that interval (20 ammeter and voltmeter readings)

Mean multiplier (21 values calculated, 1.15 to 4.45 P.M.) = 1054.25 (not used in calculations)

Station voltmeter calibrated after test by a standard (see p.)

22 readings. Mean of standard instrument = 578.0 volts. Mean of generator voltmeter = 569.7 volts. $\frac{569.7}{578.0} = .9851$.

Condensing test - Av. of mean watts for 14 (10 min.) intervals = 1,429,609

Non-condensing test - " " " " " 7 (") " = 1,189,323

$$\text{Elec. H.P. (Condensing)} = \frac{1,429,609}{746 \times .9851} = 1944 \text{ H.P.}$$

$$\text{Elec. H.P. (Non-condensing)} = \frac{1,189,323}{746 \times .9851} = 1618 \text{ H.P.}$$

Curve showing Variation of Load during Test.

Condensing Test 1.15 to 3.29 P.M.
Non. Condensing Test 3.36 to 4.44 P.M.

Calibration of Water Meter on Cooling Tower.

Tower 22'10" x 14'3" = 325.4 sq. ft.

Rise in water level = 13.19"

Volume of water added = 357.6 cu. ft.

Reading of Meter at lower level = 778 cu. ft.

" " " " upper " = 1157 "

Amount registered = 379 cu. ft.

True volume 94.35 % of amount registered.

RESULTS.

Dryness of Steam.

Condensing. (See p. 36)

Mean pressure (corrected) - 144.14 lb.

" upper temp - 357.9 °F.

" lower temp - 293.9°.

Barometer at sea level 6/8/01 - 29.92"

" " power-house " - 29.86" (assumed)

Corresponding pressure - 14.65 lb.

Absolute steam pressure - 158.79 lb.

No drip pot on calorimeter. Atmospheric pressure below orifice. Thermometers corrected by absolute pressure and "x" calculated by the equation - $q_1 + x r_1 = q_2 + r_2 + .48(T_2 - T_{atm.})$

$x = .9941$ (condensing)

Non. condensing. (See p. 37)

$X = .9948$

Water Rate.

Condensing.

See pp. 38 and 39.

Total Water.

Tank 1	32811 lb.	$\frac{69988 \times 60}{134}$ = 31339 lbs. per hr.
Tank 2	23861 "	
Tank 3 $\frac{12405}{.9316}$ =	13316 "	31339 x .9941 = 31154 lb. per hr. corrected for moisture.
	69988 lb.	940 lb. Traps.
		32094 lb. Total per hr.
		I.H.P. = 2106.6.

$$\text{Rate} = \frac{32094}{2106.6} = 15.23 \text{ lb. per I.H.P. hr.}$$

Non-condensing.

See p 39.

	Total Water	
Tank 1	19098	$\frac{40760 \times 60}{68}$ = 35964 lb.
Tank 2	13307	35964 x .9948 = 35778 lb.
Tank 3 $\frac{7784}{.9316}$ =	8355	768 " Traps
	40760	36546 Total
		I.H.P. = 1983.4

$$\text{Rate} = \frac{36546}{1983.4} = 18.43 \text{ lb. per I.H.P. hr.}$$

☞ The valves of the engine were set for non-condensing running.

Cooling Tower

Condensing Test.—

Make-up (see p.31.).. Rate = $\frac{896}{134}$ = 6.68 cu. ft. per min

= 392.9 lb. per min.

Circulating Water.— Mean difference of level in Pitot tubes (p.35) = 10.46" = .8714'. Coefficient = .7

Velocity = $.7\sqrt{2gH} = .7\sqrt{64.3 \times .8714} = 5.244$ ' per sec.

Pipes = $14\frac{5}{16}$" diam.; area cross section = 160.89 sq. in.

Cu. ft. per min. = $\frac{5.244 \times 160.89 \times 60}{144} = 351.54$

= 351.54 × 62.15 = 21848 lb. per min

$\frac{392.9}{21848}$ = 1.8 % = ratio make-up to circ. water.

Temp. entering tower = 111.9°
" leaving " = 88.3
" make up = 74.4
} (p.31.)

Heat dissipated by evaporation in tower assuming water to be evaporated at temp. of incoming water =

$$392.9\left(q_{111.9} + r_{111.9} - q_{74.4}\right) = 392.9\left(1116.1 - 42.5\right) = 421810 \text{ B.T.U.}$$

Total heat dissipated in tower = $21848\left(q_{111.9} - q_{88.3}\right)$

$= 21848(799 - 564) = 513430$ B.T.U.

Anemometer readings were taken June 14 at the outlet at the top of the tower. The mean of a number of

observations with the anemometer at various points gave a velocity of 607′ per min. The area of the opening is 325.4 sq. ft., giving 197650 cu. ft. of air per minute passing through the tower. This quantity raised in temp. about 28°F. will carry off the difference of 91620 B.T.U. per min. between the total heat dissipated by the tower and that dissipated by evaporation.

Economic Results.

41.22 H.P. Westinghouse engine

40 Assumed water-rate

1648.8 lb. water per I.H.P. hr.

32094 lb Total for main engine + traps

1649 "

33743 lb. Total water per hr.

H.P. of Air Pump and Circ. Pump Motors. (See p. 35 & p. 37)

H.P. Circ Pump Motor = $\frac{5855 \times 17.645}{2\frac{1}{3} \times 746} = 59.35$ H.P.

" Air " " = $\frac{720 \times 3 \times 19.63}{7 \times 746} = 8.12$ H.P

67.47 H.P.

41.22 " Westinghouse engine

Total power used to drive auxiliary apparatus 108.69 H.P.

I.H.P. during test = 2106.6

E.H.P " " = 1944.0

$\frac{2106.6}{1944.0} \times 67.47 = 73.11$ = I.H.P required to drive motors from generator.

Net I.H.P. = 2106.6 − 73.1 = 2033.5 H.P.

$\frac{33743}{2033.5} = 16.59$ lb. water per net I.H.P. hr.

1944. − 67.47 = 1876.53 net Elec. H.P.

$\frac{33743}{1876.5} = 17.98$ lb. water per net E.H.P. hr.

Non condensing :− (see pp. 42 and 46)

E.H.P. = 16.18

Total water per hr. = 36546 lb.

Water per E.H.P = 22.59 lb.

Saving by running condensing = 22.59 − 17.98 = 4.61 lb. water per net E.H.P. hr.

As at present arranged the exhaust from the main engine is thrown away. A hot. well, from which water will be returned to the boilers, is to be put in, and the following saving of water will be effected.

18.43 Water rate non cond
15.23 " " condensing
3.20 lb. saved per I.H.P hr.

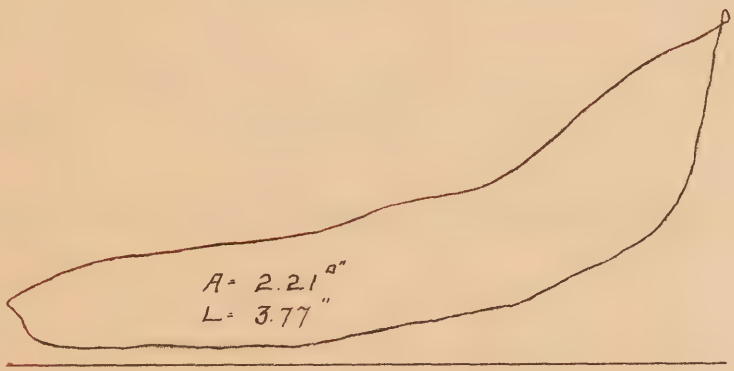
320 x 2106.6 (I.H.P) = 6741 lb. saved
392.9 x 60 = 23574 lb. make up per hr
16833 lb. excess required with condensing plant without hot well

With hot. well .. 18.43 x 2106.6 = 38825 lb. saved
23574 .. make up
15251 .. saved per hr. by running condensing.
16833
32084 lb. per hr. saved by putting in hot well over present system.

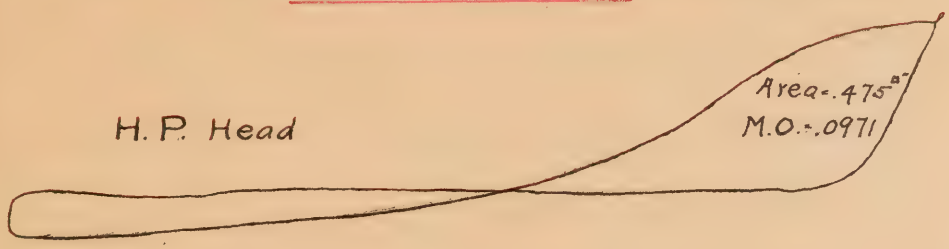
A HOT WELL WILL SAVE THE WATER NOW THROWN INTO THE SEWER OR 15.23 X 2106.6 = 32084 LBS. PER HOUR.

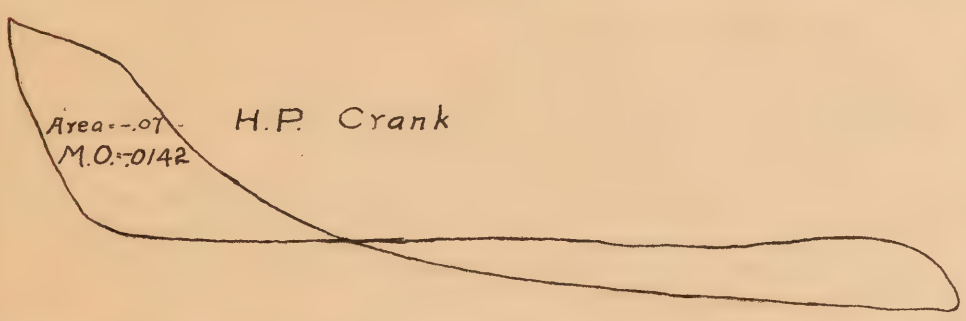
SAMPLE CARDS.

WESTINGHOUSE ENGINE.



No Load.


H. P. Head
Area=.475 sq in
M.O.=.0971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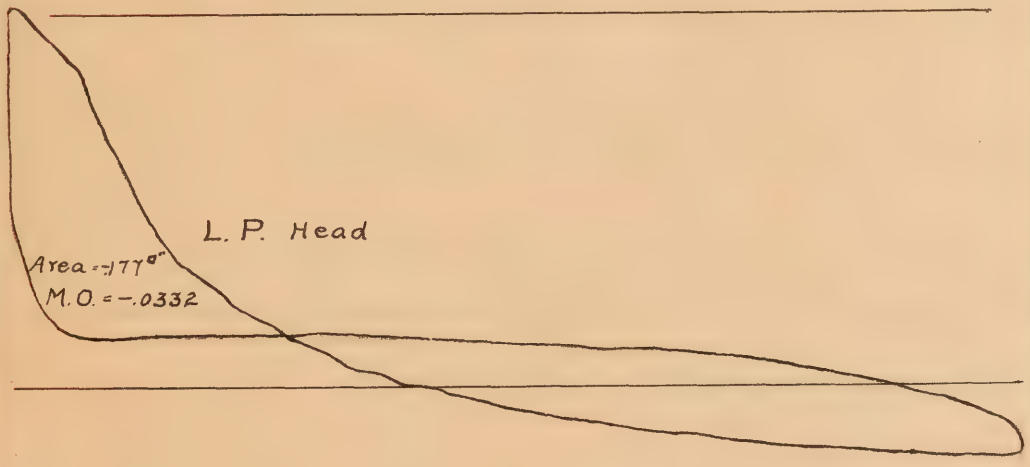
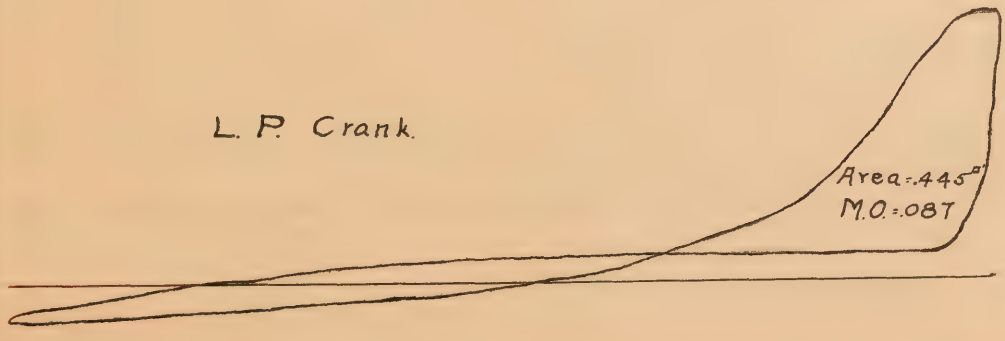
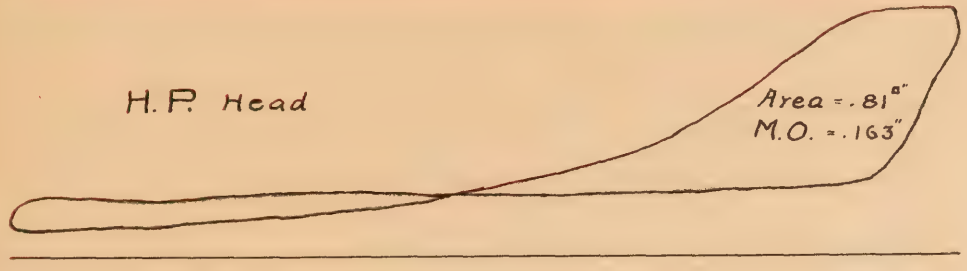
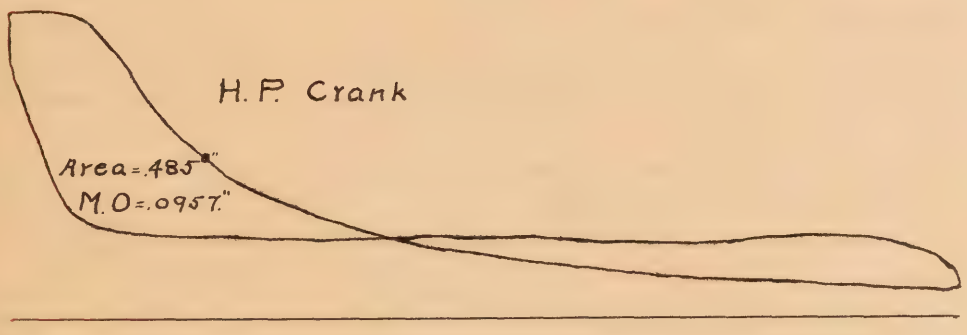
M.O.=.0142
H.P. Crank

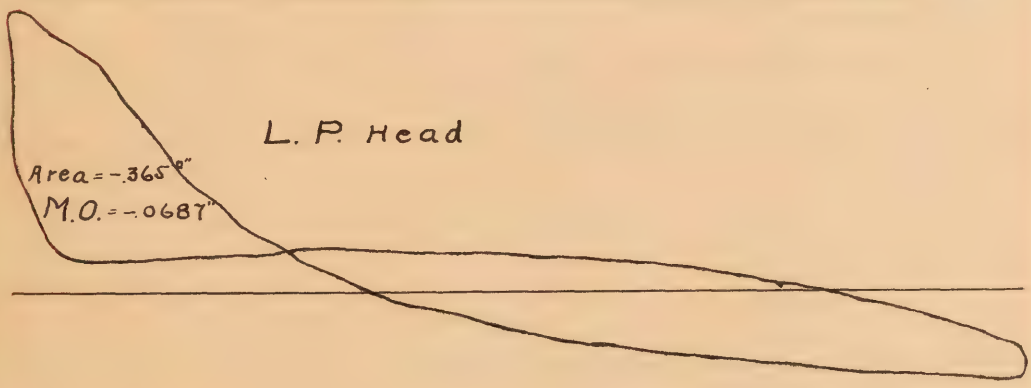

L. P. Head
Area=.177 sq in
M.O.=-.0332

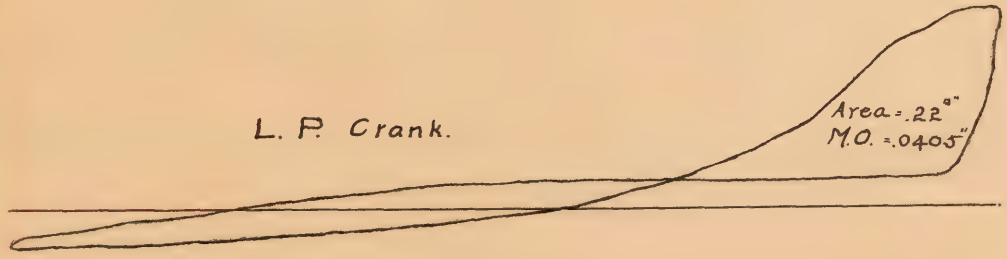

L. P. Crank.
Area=.445 sq in
M.O.=.087

FIELD EXCITED — NO EXTERNAL LOAD.

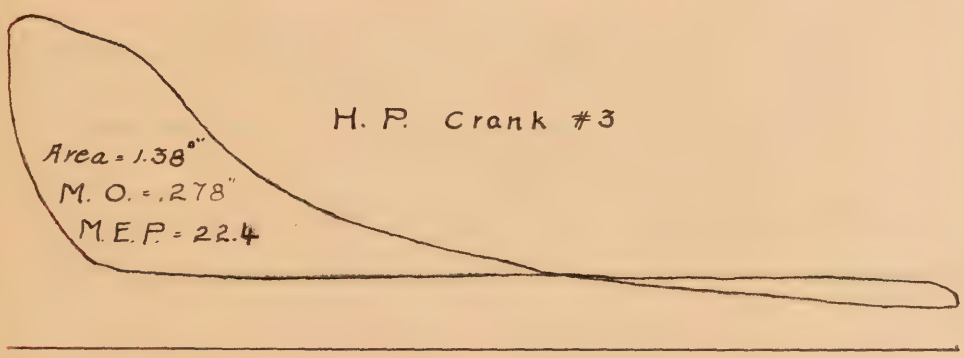


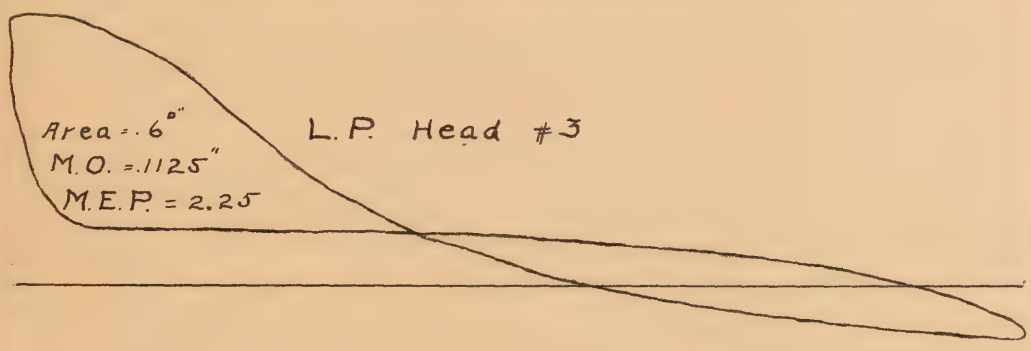


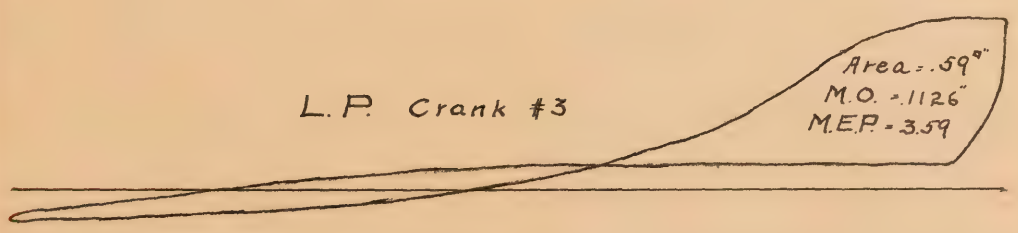




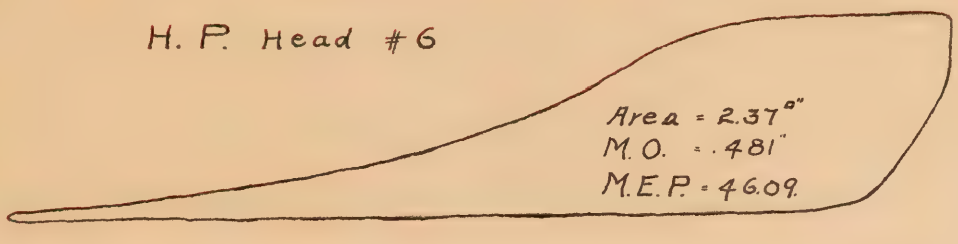
COMMERCIAL EFFICIENCY TEST.







H. P. Head #6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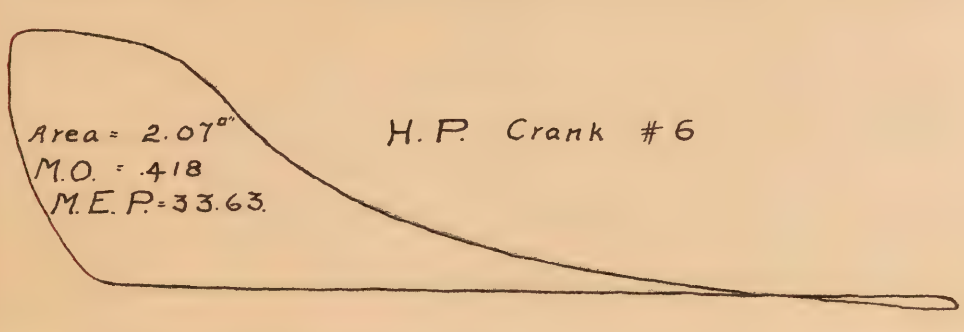
M.E.P. = 46.09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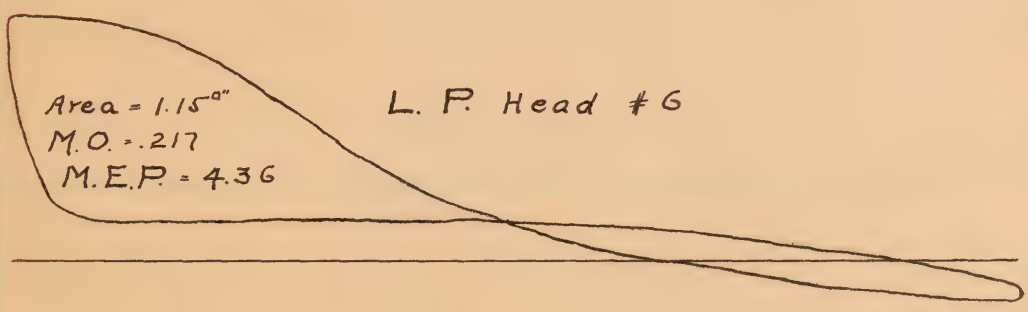
M.O. = .418
M.E.P. = 33.63
H. P. Crank #6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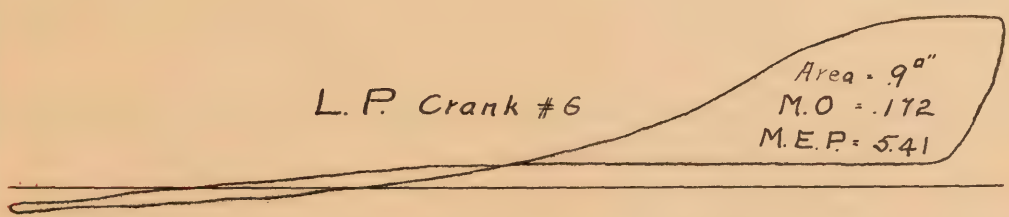
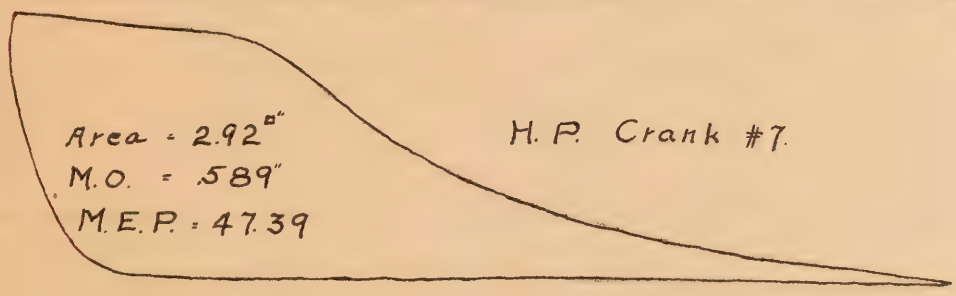
M.E.P. = 4.36
L. P. Head #6


L. P. Crank #6
Area = .9 □"
M.O = .172
M.E.P. = 5.41

H. P. Head # 7



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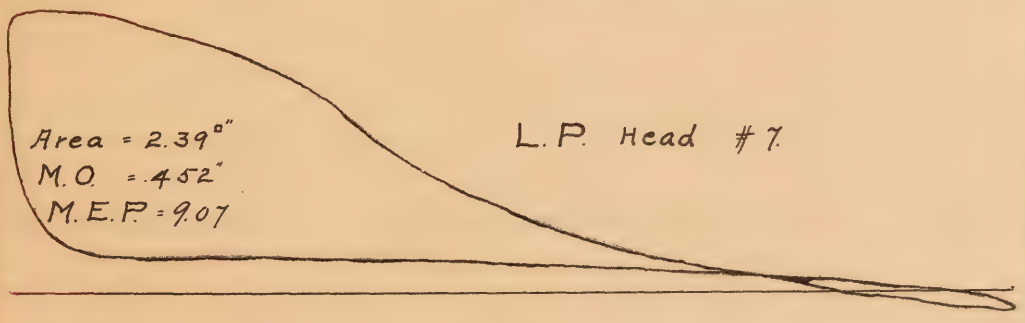
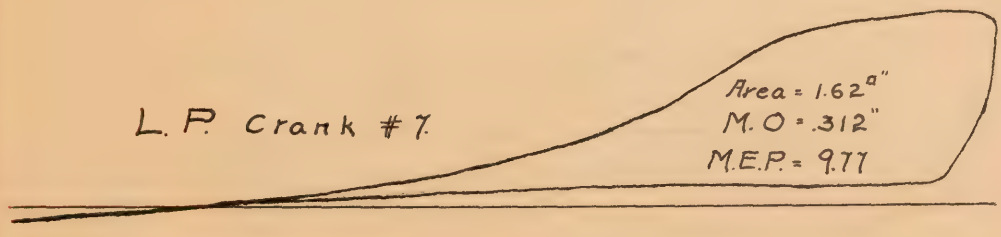


L. P. Head # 7.

L. P. Crank # 7.



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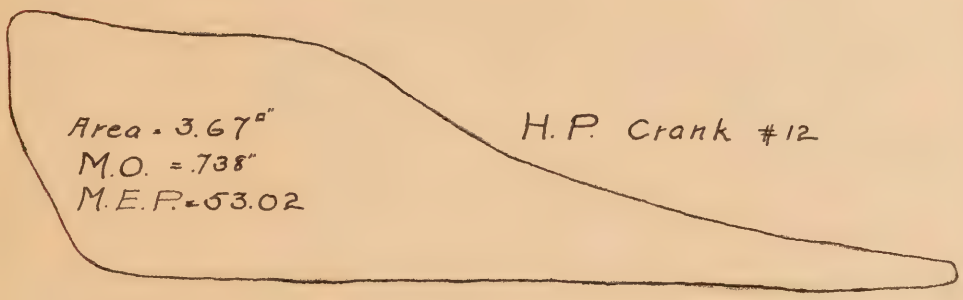
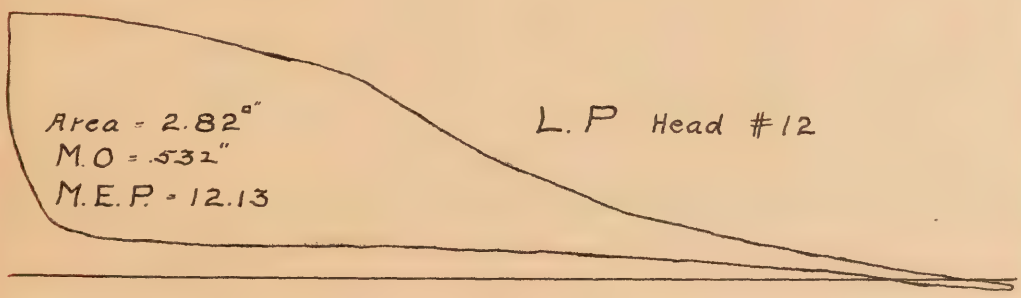
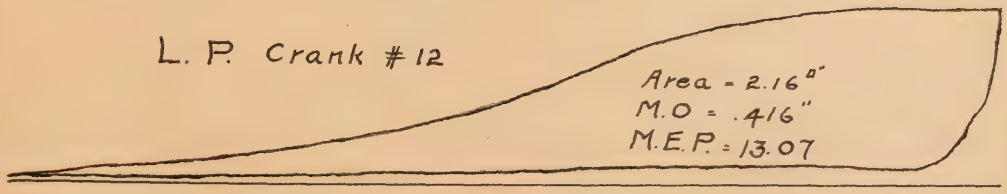
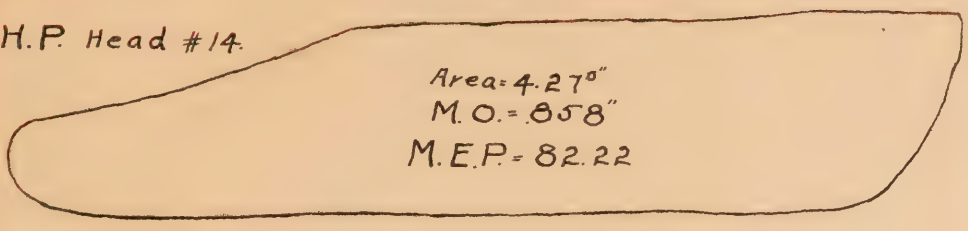


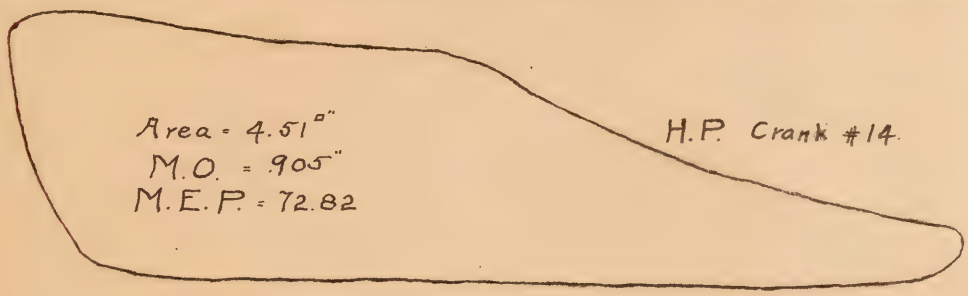


L.P. Crank #12



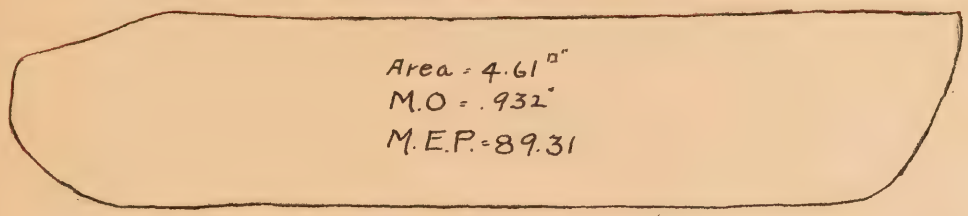
H.P. Head #14.





L.P. Crank #14

H.P. Head #16



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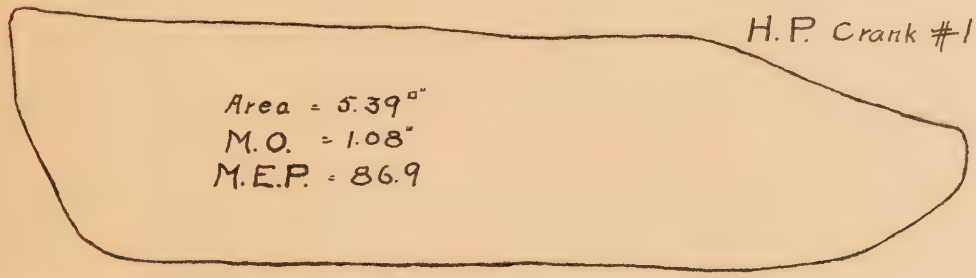

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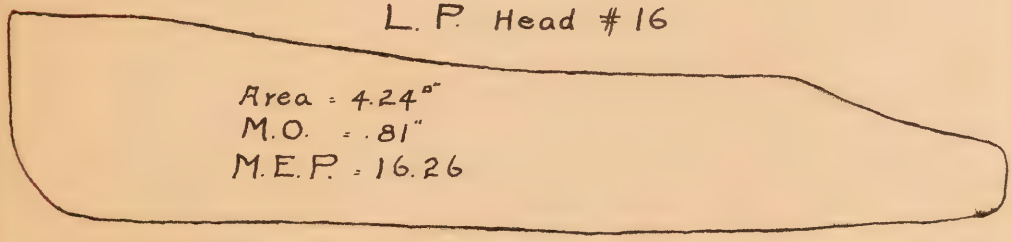
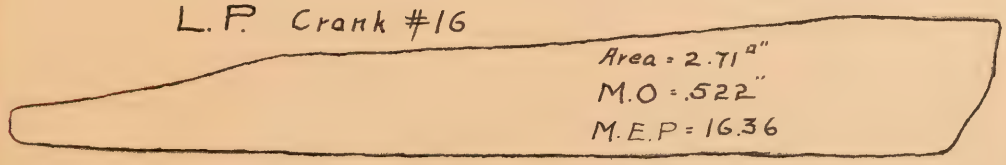
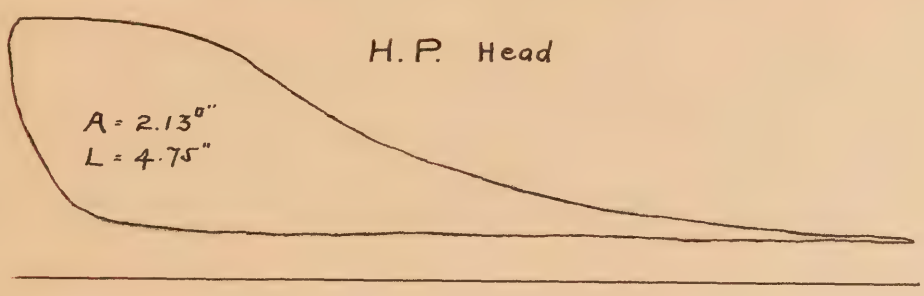


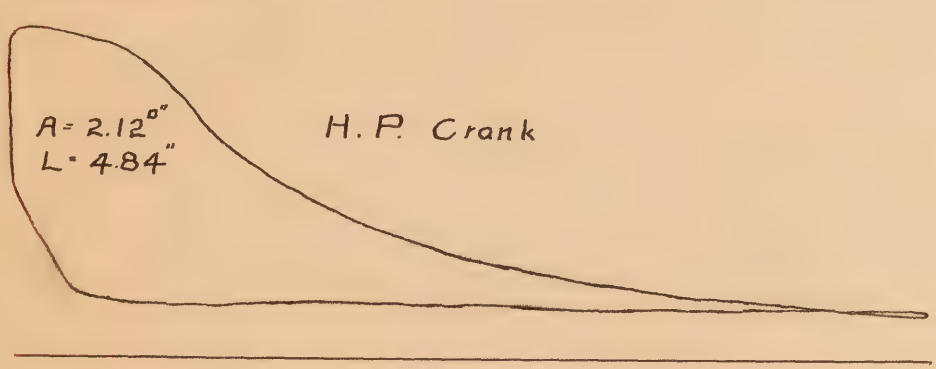
L.P. Crank #16

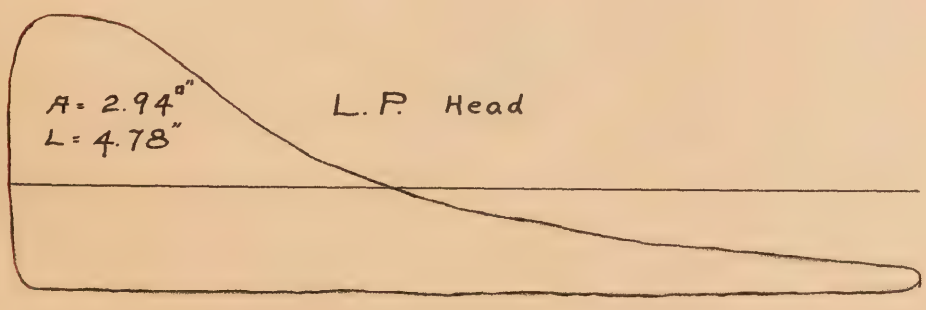


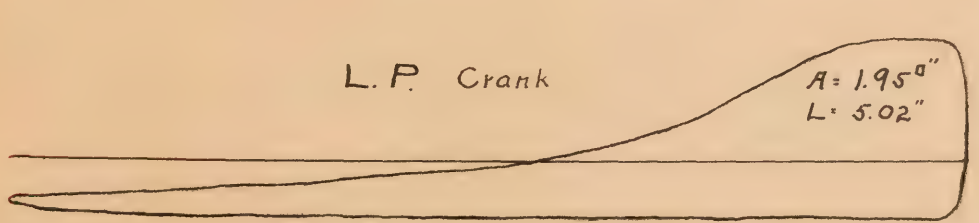
CONDENSING TEST.

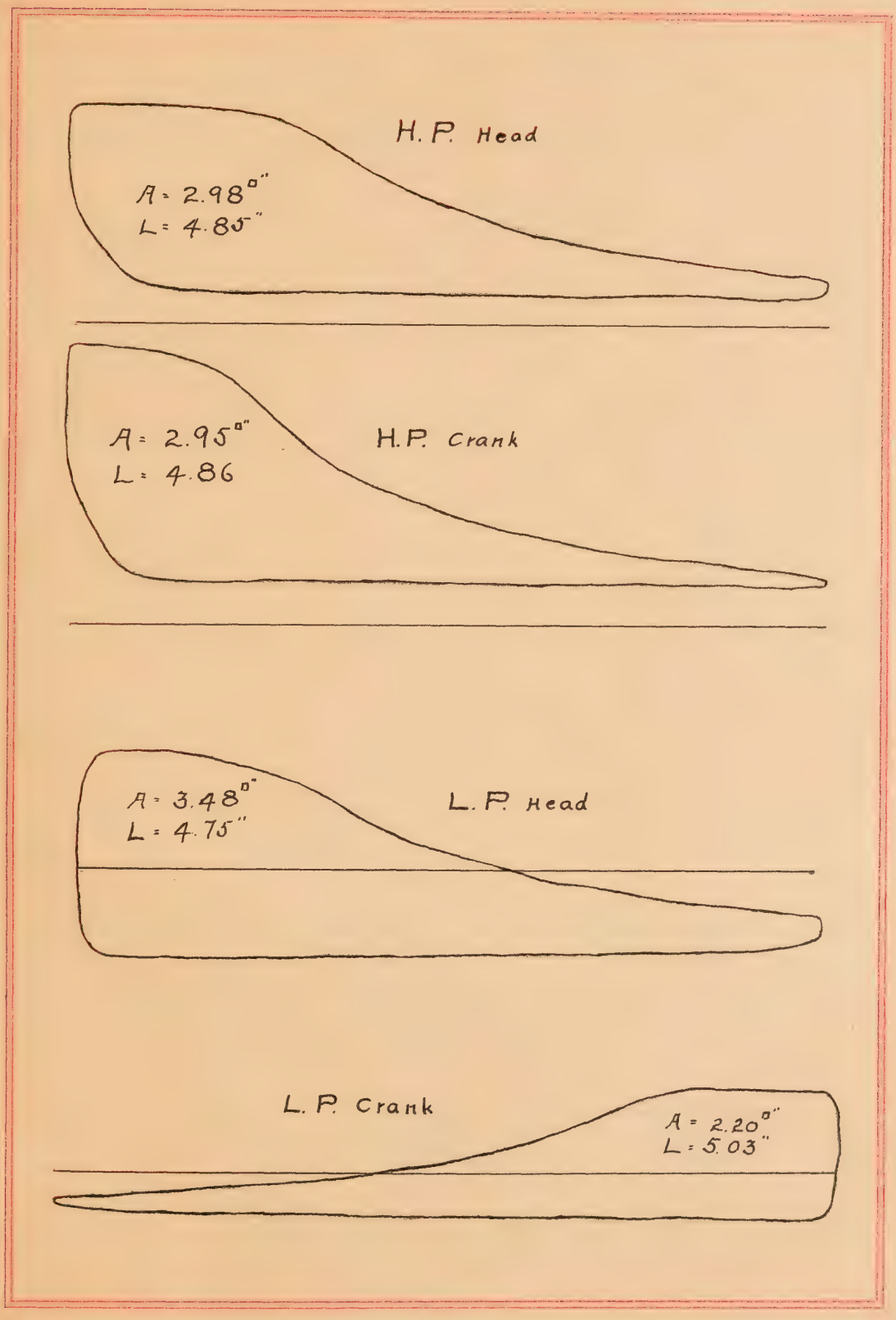
PAGES 60 TO 64. TYPICAL CARDS AT VARIOUS LOADS.

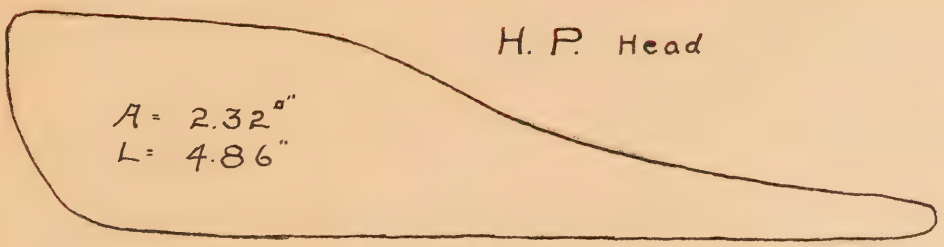


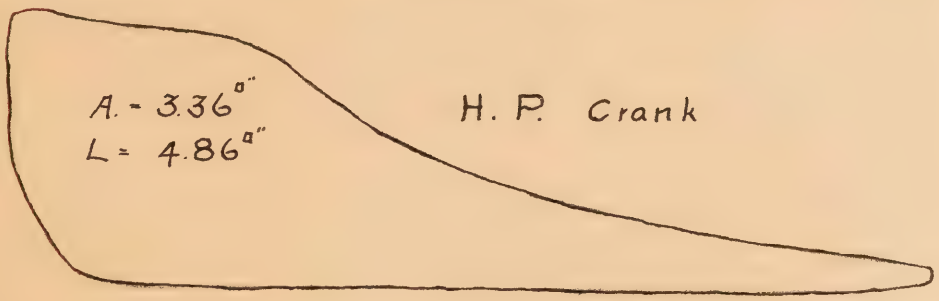


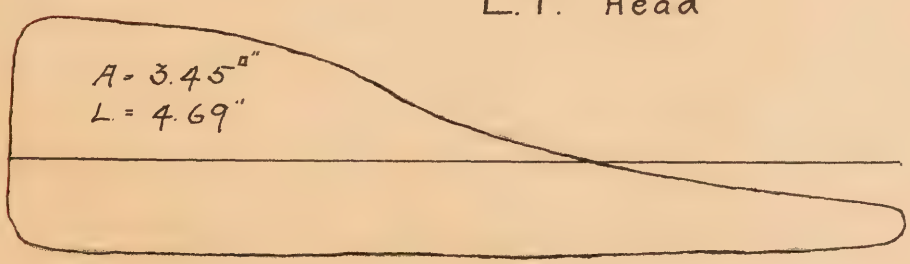


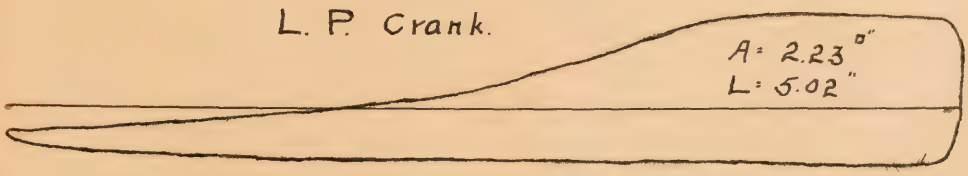



H.P. Head
A = 2.98 □"
L = 4.85"
A = 2.95 □"
L = 4.86
H.P. Crank
A = 3.48 □"
L = 4.75"
L.P. Head
L.P. Crank
A = 2.20 □"
L = 5.03"


H. P. Head
A = 2.32 □"
L = 4.86"

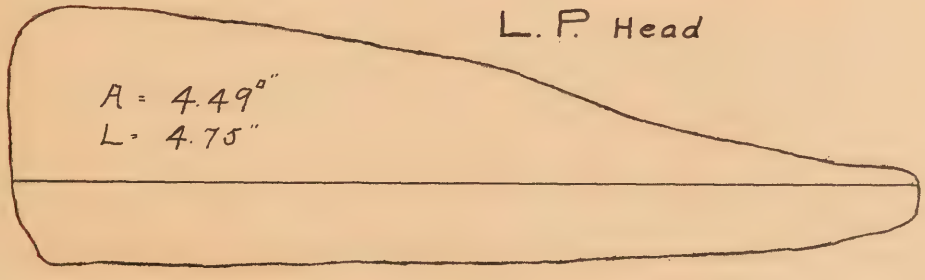

A. = 3.36 □"
L = 4.86 □"
H. P. Crank

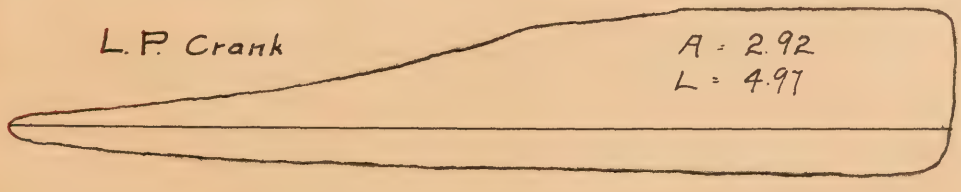

L. P. Head
A = 3.45 □"
L = 4.69"


L. P. Crank.
A = 2.23 □"
L = 5.02"

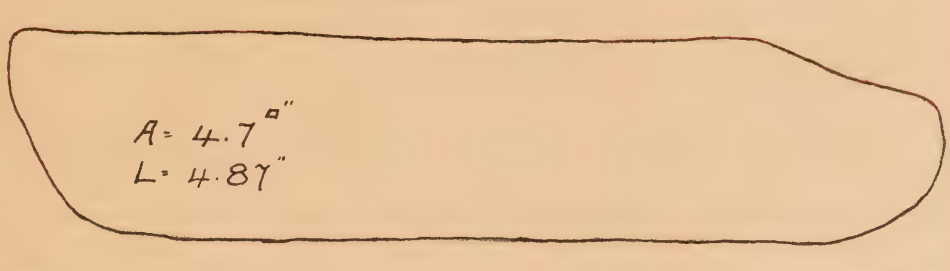
H.P. Head
A = 4.27 a"
L = 4.85"

A = 4.47 a"
L = 4.88"
H.P. Crank

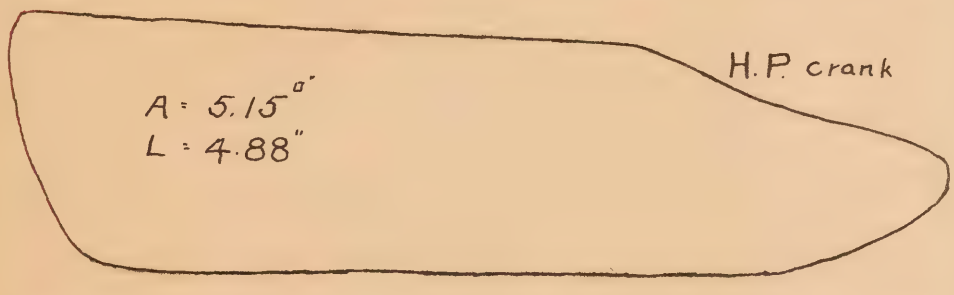

L.P. Head
A = 4.49 a"
L = 4.75"


L.P. Crank
A = 2.92
L = 4.97

H. P. Head

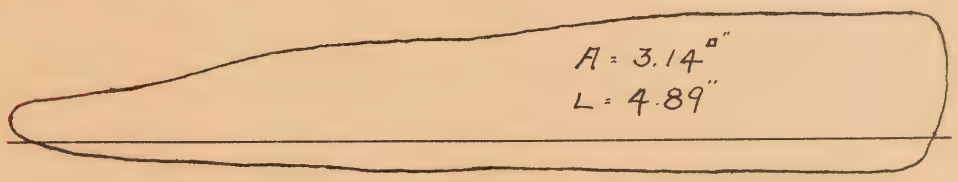


H. P. crank



L. P. Head

L. P. Crank.



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